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Impact of municipal solid waste on the water quality of Otamiri River in Owerri, South-Eastern Nigeria

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Abstract

This research aimed at assessing the influence of Municipal Waste on Otamiri River by comparing the levels of the contaminants against the set limit by regulating agencies. Stream samples were collected at five different points along the stream using the conventional WHO (2004) methods. The Physico-chemical of the samples collected were analyzed. The results were compared against the standards of regulating agencies. Spatial variations in Physicochemical parameter variations were observed in the levels of the physicochemical parameters measured across the sampling locations. Maximum levels of pH, water temperature and K^+ ions were recorded in sampling Locations (SL) 5 (7.12, 29.0^{0}C and 2.73mg/L respectively). Maximum levels of TSS, TDS and Turbidity were recorded in sampling locations 4 and 5 (568.60mg/L, 67mg/L, and 110.24 NTU respectively). Maximum levels of EC, Alkalinity and Acidity were recorded in SL 4, 5 and 1 respectively (154.30mg/L, 37.33mg/L, and 32.44mg/L respectively). Maximum levels of DO, BOD, and Chlorides (5.60 mg/L, 3.53 mg/L, and 120.60 mg/L respectively) were recorded in SL 1 and 2. Maximum levels of Ca^+, Mg^+ and Na^+ ions (64.24 mg/L, 3.60 mg/L, and 5.27 mg/L respectively) were recorded in SL 4 and 5. Maximum levels of Ammonia and Total Hardness were recorded in SL 5 (0.100 and 98.27 respectively). The constant dumping of refuse at the site has increased the concentration of organic and inorganic constituents of the river water, even though some remain within established standards. Water from Otamiri River requires elaborate treatment before it could be suitable for domestic purposes.

Keywords: Water Pollution; Municipal Waste; Physico-chemical; Spatial Variation

1. Introduction

Plants and animals require moderately pure water, and they cannot survive if their water is loaded with toxic chemicals or harmful microorganisms. According to United Nations Commission on Sustainable Development [1]. Water pollution is the introduction by man directly or indirectly of substances or energy into a body of water resulting in such deleterious effects as hazards to human health, living resources and hindrances to marine activities. Water bodies are also the primary means for the disposal of waste, especially the effluents, from industries that are near them. These effluents from industries have a great deal of influence on the pollution of the water body and can alter the physical, chemical, and biological nature of the receiving water body. Municipal Solid Waste is unwanted material that varies in composition (Figure 1) and is influenced by many factors such as culture, affluence, location etc. Unfortunately, Landfills constructed using appropriate technologies are rare in the country [2]. Even where landfills are available, the landfilling

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of household wastes without treatment or recovery is wasteful because of landfill space required and materials that could be recovered. [3]. This thus, further compounds the pollution of nearby water bodies with waste streams.

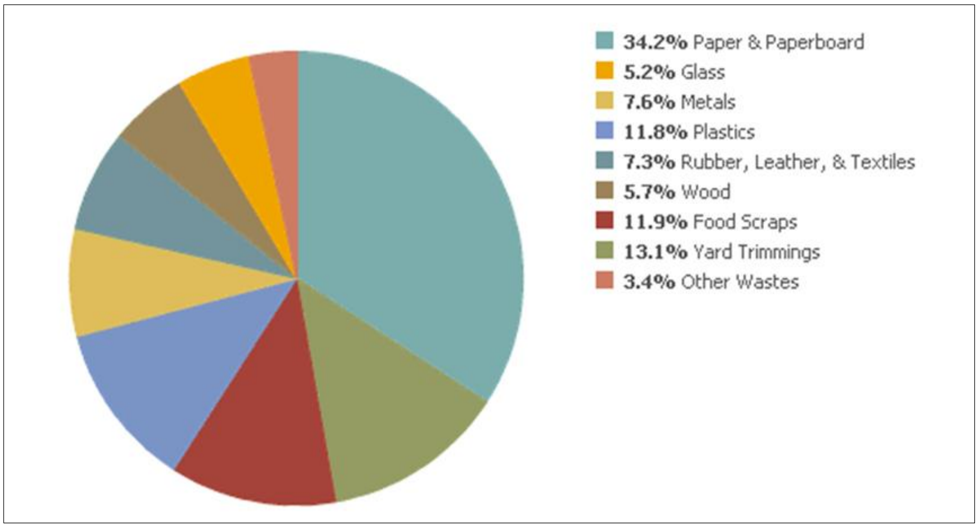

Figure 1 Components of municipal solid waste Encarta, [4]

Organic pollution of inland water systems in Africa, in contrast to the situation in developed countries of the world, is often the result of extreme poverty and economic and social underdevelopment. According to Desai and Tank [5], as societies throughout the world become more aware of the issues involved in water pollution, there has been a considerable public debate about the environmental effects of effluents discharged into aquatic environments. One of the most critical problems of developing countries is improper management of the vast amount of wastes generated by various anthropogenic activities Fakayode [6] identified that regular, unregulated indiscriminate dumping of wastes could be harmful to the environment in the end. Pollution makes streams, lakes, and coastal waters unpleasant to look at, smell, and swim in. Fish and shellfish harvested from polluted waters may be unsafe to eat due to microbial contamination.

Most cities in Nigeria including Owerri are faced with waste management problems [7]. Due to available space along Otamiri Riverbank, the Owerri Municipal Council in 2000 approved the site as the official dumpsite for most of the solid waste collected from the municipality. Consequently, solid waste has been dumped at this site for more than ten years, on a surface area approximately 11 hectares in size, 6 meters high and not compacted and capped. Nearly 30 tons of commingled wastes are dumped here daily. Waste components include metals (beverage cans, ferrous materials), used papers, rags, plastics, and organic materials (food remnants, dead leaves). A large quantity of decaying fruits and vegetables (oranges, tomatoes, cabbages, etc.) is dumped in the area. These include other elements with toxic properties (dry lead batteries, spent oils, used carbides, paints, and resins). All are dumped without any cover materials and are constantly exposed to weather and climatic conditions. During the rainy season, for example, most of these materials are washed into the river after torrential rains. The organic matter and other soluble contents in the waste dump also produce leachate that ceaselessly seeps into the soil and the river. The dumpsite then becomes a breeding ground for vectors, rodents, and pests. It is against this backdrop that this research was conducted to assess the influence of Municipal Waste on Otamiri River by comparing the levels of the contaminants against the set limit by regulating agencies.

2. Material and methods

2.1. Study Area

The study site is Otamiri River in Owerri, the capital city of Imo State, South-Eastern Nigeria.

The Otamiri River originates from a forest north of Owerri Municipality and flows southwards through the Owerri metropolis before emptying into other water bodies in the Rivers State of Nigeria. The watershed covers about 10,000 km2 with annual rainfall 2250-2500 mm and has a mean slope of 38.5% draining about 18700 hectares of land. It is characterized by depleted rainforest vegetation, with mean temperatures of 27^0C throughout the year, joined by the

Nworie River at Nekede in Owerri [8]. The river is of great significance to the people as a source of water for domestic use before the introduction of pipe-borne water in the communities.

2.2. Research Design

A semi-experimental field research design was used for the study. This allows collecting original data in a natural setting without introducing confounding variables.

A systematic point sampling design was adopted by selecting sampling locations at regular intervals as they are encountered. This approach often provides greater information because the sample is distributed uniformly over the entire study area and because of its ease of use in field studies.

2.3. Sample Selection

Stream samples were collected at five different points along the stream using the conventional WHO [9] methods. Five rural communities were selected as the point of sample collection. Water samples from Otamiri River were obtained from locations closest to landfill, mechanical workshop village and sand and gravel mine for four months: September to December. Samples were taken once every month at the early hours of the day. Site location 1 was located 300m from the source of the stream at Egbu village near Owerri and served as the control. Site Location 2 was located at 300m from Site Location 1, and about 31m from the dumpsite, while Site Location 3 was located downstream behind Emmanuel College premises, at about 300m from Site Location 2. Finally, the sample collected at Site Location 4 was a composite sample collected from the riverbanks around Nekede village; about 310m from Sample Location 3 and at 1m below the water surface. Site Location 1 and Site Location 5 is the downstream and upstream samples respectively.

2.4. Instrument for Sample Analysis

The containers were unscrewed at a depth of 15-30cmbelow the surface of the water, facing the upstream direction and corked when filled while still underwater to prevent oxidation. A small air space of 2 to 3 cm above the sample was left in the container for proper mixing of the sample before analysis except for the water samples for biochemical oxidation demand (BOD) and dissolved oxygen (DO) determination. It was tightly closed and labelled. Bottles were rinsed with the river water before sampling. These were stored in the icebox to retard the biochemical activities and promptly transported to the laboratory.

2.5. Sample Analysis

The samples collected were analysed as per standard methods mentioned in [10]. The water samples were subjected to filtration; the sample bottles were immediately corked underwater to prevent oxidation. Of the three samples collected, one was immediately analysed for the following parameters in the field: pH, Temperature, Electrical Conductivity Total Dissolved Solids (TDS) and Dissolved Oxygen) using Digital Meters. Serial dilution of the water samples was carried out using sterile distilled water. The standards reagents used in the analysis were prepared using double distilled water.

2.5.1. Test of Biochemical Oxidation Demand, Acidity and Dissolved Oxygen

The BOD was evaluated by first diluting the sample and incubating it in the dark at 20°C for five days and measuring the amount of oxygen consumed. The DO sample was fixed with 2ml each of Wrinkler I and II reagents at the site, while BOD_5 sample bottles were corked and wrapped with aluminium foil and the BOD_5 sample was fixed with the Wrinkler method after five days of incubation at room temperature (25°C) in the dark place. Conductivities were measured at 25°C directly in µs/cm using a digital conductivity meter (NorLab; LM8). Turbidities were measured with a digital Turbidimeter (Hach Chemicals;2100P). The total suspended and total dissolved solids were separated by filtering the water through a 0.45µm filter paper and determined according to standard procedures [10].

Acidity and alkalinity were determined by titration methods. Dissolved oxygen was determined using a dissolved oxygen meter; In this case, the dissolved oxygen (DO) of the samples was determined using the Schott Gerate Dissolved Oxygen meter and then incubated for five (5) days at 20^0C. DO was again measured after five days and BOD in mg/1 was determined from the following calculation and reported accordingly. BOD_5 was determined using BOD_5 Track; electrical conductivity was measured by electrical conductivity meter – DIST3 by HANNA limited. Ammonia–Nitrogen (NH_3-N) was determined by direct Nesslerization for natural effluent and Nitrate – Nitrogen (NO_3-N) was determined by the Brucine method (Ademoroti, 1996). Their absorbance values were read with UNICAM 8626 UV/VIS spectrophotometer at 470 nm for NO_3-N and PO_4 and 420 nm for SO_3 ions.

2.5.2. *Test for the presence of nitrite*

The test for the presence of nitrite was carried out using a modification of the method described by [11] which involves the Greiss-Ilosvay reagent. Suspensions had to be prepared by dissolving some part of the isolated cultures from the selective medium in 1 ml of sterile deionised water.

2.5.3. *Test for Phosphorus*

This was determined using Vanado-molybdophosphoric acid colourimetric method using ammonium molybdate which formed molybdo-phosphoric acid under acidic conditions. The intensity of the yellow colour was measured using a spectrophotometer at 490 nm.

3. Results

The Physico-chemical parameters and contaminants found in the samples from the predetermined spots in Otamiri River, Imo State, Nigeria are presented in Table 1.

Table 1 Descriptive statistics of the physicochemical parameters

parameters	Minimum	Maximum	Range	Mean	SE
pH	6.23	7.12	0.89	6.5240	0.17137
TSS	112.80	568.60	455.80	320.5400	90.42545
EC	60.13	154.30	94.17	87.6780	17.46188
Acidity	28.45	32.44	3.99	30.0820	0.66453
TDS	49.00	67.00	18.00	55.4000	3.31059
Turbidity	10.60	110.24	99.64	72.7260	17.94098
DO	3.76	5.60	1.84	4.6760	0.31752
BOD	2.50	3.53	1.03	2.9200	0.21324
Cl	20.20	120.60	100.40	63.6000	20.14229
Alkalinity	30.24	37.33	7.09	32.6960	1.30086
T_Hardness	39.27	98.27	59.00	69.8240	11.63673
Ca	1.47	64.24	62.77	16.1780	12.04413
Mg	2.24	3.60	1.36	2.6820	0.27240
K	2.54	2.73	0.19	2.5980	0.03455
Na	3.27	5.27	2.00	4.5540	0.35413
PO4	.10	10.23	10.13	5.5120	1.96288
SO4	1.98	2.66	0.68	2.3940	0.12883
NO3	2.80	4.22	1.42	3.5840	0.28335
NH3	0.003	0.100	0.097	0.03740	0.018041
Temperature	25.00	29.00	4.00	27.1400	0.76785
Fe	0.14	1.04	0.90	0.4240	0.16080

SE= standard error of mean; TSS=Total Suspended Solids; EC=Electrical Conductivity; TDS= Total Dissolved Solids; Do=Dissolved Oxygen; BOD= Biological Oxygen Demand; CL= Chlorides; T hardness= Total Hardness; Ca= Calcium; Mg= Magnesium; K= Pottasium; Na= Sodium; PO_4= Phosphates; SO_4= sulphates; NO_3= Nitrates; NH_3 =Ammonium; Fe = Iron; THBC= Total Heterotrophic Bacterial Count; TCC= Total Coliform Count; TFC= Total Fecal Count; COD= Chemical Oxygen Demand.

The levels of the physicochemical parameters of the Otamiri River are shown in Table 2. Total Suspended Solids (TSS) (Range =455.80) Electrical Conductivity (EC) (Range =94.17) Turbidity (Range =99.64), chloride ions (Range =100.40), Total hardness (Range =62.77) had comparatively wider variations than the other parameters. pH, Total Suspended Solids (TSS) and electrical conductivity (EC) varied from 6.23 - 7.12 (6.52 ± 0.17), 112.80-568.60(320.54± 90.43) mg/L and 60.13- 154.30(87.68 ± 17.46) µS/cm respectively (Table 1).

Table 2 Descriptive statistics of Physico-chemical parameters samples from site locations

Parameters	SL1	SL2	SL3	SL4	SL5	NAFDAC	WHO
pH	6.27	6.30	6.23	6.70	7.12	6.5-7.5	6.5-7.5
TSS(mg/l)	120.3	112.8	345.9	455.1	568.6	6.5-8.5	500
EC (µs/cm)	60.13	64.2	69.2	154.3	90.56	-	40
ACIDITY	32.44	30.34	28.45	29.76	29.42		ns
TDS(mg/l	49	49	57	55	67	50	50
Turbidity(NTU)	10.6	56.34	98.78	110.24	87.67	-	5-25
DO(mg/L)	5.6	5.12	4.34	4.56	3.76	7.5	7.5
BOD_5(mg/L)	3.33	3.53	4.50	4.70	5.54	<4	<4
Chloride(mg/L)	20.2	25.8	50.6	100.8	120.6	200	200-400
Alkalinity(mg/L)	30.25	30.24	32.43	33.23	37.33	100	80-120
Total hardness(mg/L)	39.27	55.34	60.54	95.7	98.27	-	100-500
Calcium(mg/L)	1.47	3.45	6.2	6.24	5.53	75	75-200
Magnesium(mg/L)	2.29	2.24	2.26	3.02	3.60	30	0.5-0.1
Potassium(mg/L)	2.55	2.57	2.60	2.54	2.73	10	10-45
Sodium(mg/L)	3.27	4.67	4.44	5.12	5.27	Not applicable	200
Phosphate(mg/L)	0.10	1.78	6.78	10.23	8.67		0-5
Sulphate (mg/L)	198	221	254	258	266	200-400	200-400
Nitrate(mg/L)	2.8	30.4	33.7	40.9	42.2	-	10
Ammonia(mg/L)	0.003	0.007	0.023	0.054	0.1	0.5	0.5
Water Temperature(^{0}C)	28.7	25	26	27	29	29.9	0-30
Iron(ppm)	1.04	0.42	0.30	0.22	0.14	0.3	0.3
COD	6.7	9.2	14.9	45.2	40.6	<10	<10

All parameters in mg/l except pH; organic matter (%) bulk density (gcm^2) and iron(ppm); DO= dissolved oxygen; PO_4^{-3}= phosphates; TOC= Organic Carbon; BOD= biochemical oxygen demand; COD= chemical oxygen demand; EC= electrical conductivity.

Spatial variations in Physicochemical parameter variations were observed in the levels of the physicochemical parameters measured across the sampling locations. Minimum levels of pH (6.23), water temperature, (25.0^{0}C) and K^+ ions (2.54mg/L) were recorded in sampling locations (SL) 3, 2 and 4, while their maximum Levels (7.12, 29.0^{0}C and 2.73mg/L) were all recorded in SL5. Minimum levels of TSS (112.80mg/L), TDS(49mg/L) and Turbidity(10.60 NTU) were recorded in sampling locations (SL) 2 and 1 while their maximum levels (568.60mg/L, 67mg/L, and110.24 NTU) were recorded in SL 4 and 5. Minimum levels of EC (60.13µs/cm), Alkalinity (30.24 mg/L) and Acidity (28.45 mg/L) were recorded in sampling Locations (SL) 1,2,3 while their maximum levels (154.30 mg/L, 37.33 mg/L, and 32.44 mg/L) were recorded in SL 4,5 and 1 respectively. Minimum levels of DO (3.76 mg/L), BOD (2.50 mg/L), and Chlorides (20.20 mg/L) were recorded in sampling Locations (SL) while their maximum levels (5.60 mg/L, 3.53 mg/L, and 120.60 mg/L) were recorded in SL 1 and 2. Minimum levels of Ca^+ (1.47 mg/L), Mg^+ (2.24 mg/L) and Na^+ (3.27 mg/L) ions were recorded in sampling Location SL1 while their maximum levels (64.24 mg/L, 3.60 mg/L, and 5.27 mg/L) were recorded in SL 4 and 5. Minimum levels of Phosphate (0.10 mg/L), Sulphate (1.98 mg/L) and Nitrate (2.84 mg/L) ions were recorded in sampling Location (SL) 1 while their maximum levels (10.23 mg/L, 2.66 mg/L, and 4.22 mg/L) were recorded. Minimum levels of Ammonia (0.003 mg/L) and Total Hardness (39.27 mg/L) were recorded in sampling Locations (SL) 1 while their maximum levels (0.100 and 98.27) were recorded in SL 5.

4. Discussion

According to Adeyemo [3], Nigeria's vast freshwater resources are among those most affected by environmental stress imposed by human population growth, urbanization and industrialization and the major culprit is disposal and management of wastes accrued from these human activities. The increased turbidity of the water at sample location 4 is an indication of the input of wastes from the municipal waste dump.

The progression of water conductivity level that increased from 60.13microhms/cm at control point SL1 to 154.3microhms/cm at SL4 (an increase of about 52 per cent) reflects the status of inorganic pollution and is a measure of TDS in water. This far exceeds the NAFDAC and WHO maximum permissible limit (Table 2). Comparing these values with 40 micros/cm, which is the drinking water standard by WHO [9], this concentration level poses a great threat to the health of the local population that uses the river water as a source of water supply. Freshwater streams ideally should have a conductivity of 150 to 500 µS/cm to support diverse aquatic life [10]. TDS were not within permissible levels according to WHO [13] in SL3 and SL4.

Comparing the mean pH of the water samples showed that their pH level was between 6.0 and 8.5, within the range of the standard limit for safe drinking water by WHO.

Total Hardness was within permissible limits with SL5 being the highest at 98.27mg/l. The total hardness of the water was recorded (40 to 99mg/l). The water is hard and is thus largely unsuitable for direct use by communities that use it for laundry work and bathing. Calcium and Magnesium hardness range from 1.47mg/l to 6.24mg/l and from 2.24 to 3.6 mg/l respectively. The mean concentration of calcium and magnesium is 84.22 and 60.20 mg L^{-1} respectively which are below the recommended permissible limit of 200.00 mg L^{-1} for both calcium and magnesium [14].

Leachates from fertilizer and waste disposal can lead to high nitrate concentration which causes eutrophication [13]. Phosphate levels varied along with the sampling locations, the highest recorded at SL4 (10.23mg/l). These findings agree with the findings of [15] which also recorded values above the permissible limits. Larger streams may react to phosphate only at levels approaching 0.1 mg/L, while small streams may react to levels of $PO4^{-3}$ at levels of 0.01 mg/L or less. According to Nwaugo *et al.* [16] in general, concentrations over 0.05 will likely have an impact while concentrations greater than 0.1 mg/L will certainly have an impact on a river. The mean levels for chloride, phosphates, sulphates, nitrates and ammonia were found to be significantly at variance with the safe limits for drinking water of 200-600mg/l for chlorides; 0.5mg/l for phosphates; 200-400mg/l for sulphates and 0.5mg/l for ammonia [14]. Most domestic wastes contain chlorides and phosphates. The mean sodium and sulphate concentrations are 4.60 and 23.94 mg L^{-1} respectively and values are below the permissible limit of 200.00 and 100.00 mg L^{-1} for sodium and sulphate respectively [14].

The mean concentrations of dissolved oxygen (DO) of Otamiri vary from 3.76 to 5.6 mg/l with a mean value of 4.6mg/l. In their Classification of surface water, Diese [17] indicates that surface water with DO of 6.2 and 7.8 mg/l, falls within acceptable and excellent levels, respectively. SL1 (upstream) had DO mean values within the acceptable (5.6mg/l). This indicates less organic waste input which provides enabling environment for aquatic life. The midstream, SL2 and SL3 however had relatively lower DO values. This could be attributed to the impact of municipal wastes dumped in the river directly or through runoff. Nnaji and Duru, [18] maintain that Microbial breakdown of the organic material leads to higher DO utilization and reduction.

The BOD values from SL 3-5 were higher than the 4.0mg/l standard limit, except for values from location 1 (upstream) which is within the standard. Because the oxygen demand probably exceeded the available oxygen. The oxygen demand is directly proportional to the amount of oxygen waste materials that are to be broken down [19].

Findings on COD levels show that there was an increase from 6.7mg/l to 40.6mg/l. This is due to the increase in oxygen needed to convert more suspended organic solids to carbon IV oxide and water at dumpsite relative to the control point. This increase in oxygen demand reflects also the depletion of dissolved oxygen at the dumpsite relative to the values as the control point. Water containing high solids may cause laxative or constipation effects. The values from SL3-5 are higher than the acceptable permissible limit of 10.00mg L^{-1} or less [14]. The COD determination provides a measure of the oxygen equivalent of the portion of organic matter in water that is susceptible to oxidation by a strong chemical oxidant. It determines the quantity of oxygen required for the oxidation of organic and inorganic matter in water. The high concentration of COD in the surface water is an indication that the solid waste is highly polluted with oxidizable organic and inorganic pollutants [20]. The high BOD and high COD values are indicative of the presence of organic and inorganic pollutants, respectively. It however falls within the range of polluted waters (20–200 mg/L).

The mean temperature values of the water samples are not statistically different from each other ($p < 0.05$) and also fall within the normal temperature range supportive of good surface water quality which is 0 °C to 30 °C.

The significantly high total suspended solids (TSS) and total dissolved solids (TDS) of the water ($p < 0.05$) are implicative of a high level of pollution of the Otamiri River when compared to the WHO standard limit for good water quality which is 500 mg/L for TSS and 50 mg/L for TDS.

5. Conclusion

The constant dumping of refuse at the site has increased the concentration of organic and inorganic constituents of the river water, even though some remain within established standards. The fact is that contaminants generated within the waste dump during decomposition of the biodegradable components of the waste enter into the water body affecting its quality and ecological health of the river, water from Otamiri River requires elaborate treatment before it could be suitable for domestic purposes. It was also observed that the levels of TDS, alkalinity, total hardness, calcium, potassium, sodium, conductivity, chloride, nitrates, sulphates, ammonia and phosphates in sections downstream were higher than those from the upstream sections. These higher levels were attributed to human activities in the river.

A management plan to restrict the dumping of wastes into the Otamiri River is needed to reduce the impact on water quality and pollution-related health problems. Otamiri River demands appropriate monitoring procedures for pollution control and mitigation for sustainable development of the resource. The quality of the river water can be raised to the WHO standards for safe drinking water by applying the necessary treatment procedures. For instance; the pH can be corrected using sodium bicarbonate (soda ash) while the microbial assay can be improved upon by boiling and subjection to treatment using chlorine.

Public awareness can be created on appropriate waste management practices such as is in the area of public enlightenment and environmental and health education. Residents of these areas should be educated on the effect of improper dumping of refuse.

Compliance with ethical standards

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The authors declare that there is no conflict of interest in publishing this article.

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